Seed Treatment for Control of Seed-Corn Maggot and Seed Decay Organisms

By W. L. Howe, W. T. Schroeder,
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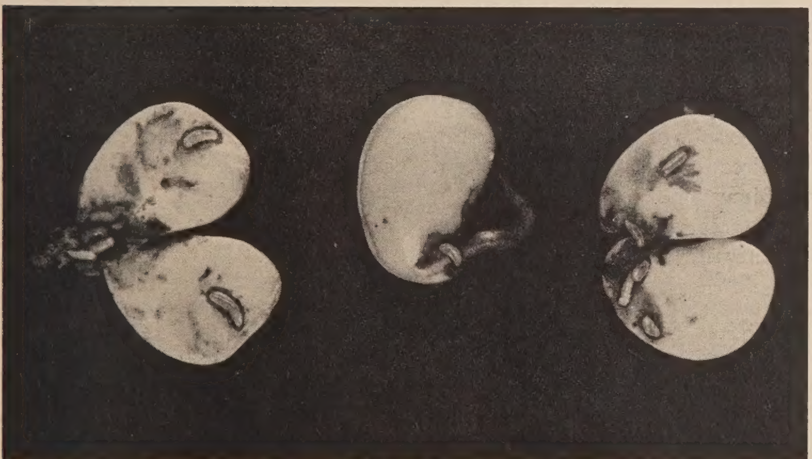

Typical Seed-corn Maggot Injury to Lima Bean Seed.

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Contents

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ABSTRACT

THE seed-corn maggot, *Hylemya cilicrura* (Rond.), causes serious damage to germinating bean seed in western New York. Conditions favorable for maggot infestation are also favorable for seed decay organisms. To obtain adequate stands of beans, it would be desirable to control both the maggot and decay-producing organisms.

Reliable control was obtained with a combination insecticide-fungicide seed treatment. The use of either an insecticide or a fungicide alone generally resulted in unsatisfactory stands.

The seed treatment recommended consists of 1⅓ ounces of Arasan SF plus 1 ounce of aldrin, chlordane, dieldrin, or lindane.

With treated seed, satisfactory stands can be obtained from plantings made as early as the middle of May. In the past, lima beans have seldom been planted before early or mid-June in western New York.

Treated seed was stored at 40° to 50° F for 58 weeks without injury to the seed or reduction in the efficiency of the treatment. Treated seed stored at 70° to 80° F showed marked injury after 31 weeks. The injury was apparently due to the high temperature since it also occurred to untreated seed stored for the same period.

Introduction

THE FAILURE of beans and some other crops to produce adequate stands in western New York is due to a combination of two factors. One is the injury to the germinating seed produced by the feeding of the seed-corn maggot. The other is the action of soil-inhabiting bacteria and fungi which cause seed decay. Previous work on treating bean seed with fungicides alone has shown some, but not always satisfactory, increase in stand. When insecticides were used without a fungicide, a similar situation resulted. This bulletin reports the development of a seed treatment which, by taking into consideration the dual nature of the injury, increases to a satisfactory level the stand of crops susceptible to maggot injury.

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Organisms Responsible For Injury

Seed-corn maggot

The seed-corn maggot, *Hylemya cilicrura* (Rondani), belongs to a group of flies whose larvae (maggots) inhabit the soil and feed upon germinating seeds, underground parts of plants, and other organic material. This group also includes the cabbage maggot and the onion maggot. The seed-corn maggot is a serious pest in Europe, southern Canada, and throughout the United States, and is also found in other areas of the world.

In western New York the seed-corn maggot overwinters in the soil in the pupal stage from which adults emerge during early and mid-May. Oviposition begins 1 to 2 weeks after emergence. The eggs hatch in 2 to 4 days, and another 9 to 15 days are required for the larvae to reach the pupal stage which is of 9 to 14 days' duration. The second brood adults emerge from these pupae and probably reach maximum numbers from late June to mid-July. Variable weather conditions from year to year may cause considerable variations in the time necessary for the completion of any particular stage or generation and, consequently, in the time of appearance of the adults of any generation. According to Hawley (3),[2] a few third brood flies may emerge from the second brood pupae in August and September, and some of these may hibernate. However, most of the flies which appear in the spring of the next year are believed to come from overwintering pupae of the second generation.

The seed-corn maggot feeds on the seeds of a wide variety of plants. It is important in connection with the black-leg disease of potatoes, although in this respect it has not been serious in New York. It has also caused damage to spinach seedlings, feeding on the lower stalk and petioles which are partially covered by soil (6). In plantings of vegetable crops the seed-corn maggot is, in general, most serious in those crops having large seeds. Among the vegetable crops most seriously affected are beans, corn, squash, and peas.

In beans, maggot injury is more severe in the large-seeded varieties, and thus the large-seeded lima beans are most severely injured (Fig. 1). Bean seeds become susceptible to maggot injury after germination begins. If the maggot infestation is heavy, enough of the germinating seed may be destroyed so that no seedling develops. When the maggots feed on the plumule, the entire growing point may be

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[2]Numbers in parentheses refer to Literature Cited, page 34.

Fig. 1.—Top, *uninjured lima bean seed;* center, *injury predominately due to seed-corn maggot;* bottom, *injury resulting from both maggot and seed decay organisms.*

Fig. 2. — Seed-corn maggot injury to lima bean seedlings. Uninjured plant at left; others show severe or "baldhead" condition.

destroyed, resulting in emergence of the type of seedling commonly called "baldhead" or "snakehead" (Fig. 2). If only a portion of the plumule is consumed, the primary leaves are deformed and growth is retarded (1).

Prior to successful control by seed treatment, the most practical control measure was planting during the "fly-free dates" (8). The object is to delay planting until after the first brood of maggots pupate and before the larvae of the second brood appear. This period is of about four days' duration, usually beginning between June 7 and 14 in western New York. The short duration of the planting period constitutes the chief disadvantage of this control measure. It not only entails late planting, but, also, the period for sowing is so short that it may not coincide with suitable soil and weather conditions. The exact time of occurrence of the "fly-free dates" is difficult to predict for a large area. The time of occurrence may vary from year to year, between various parts of the State, and sometimes even from field to field.

Seed decay organisms

The invasion of the germinating seed before emergence by various bacteria and fungi results in injury commonly called seed decay or preemergence damping-off. Postemergence damping-off refers to a similar attack on the plant, usually at or below the soil line, after the seedling has emerged. In preemergence damping-off the seed, or seedling, may be completely destroyed. Frequently, however, only a portion of the seed is invaded and the seedling emerges, although considerably weakened.

The organisms capable of causing seed decay are numerous and varied, including both bacteria and fungi. Among the most common fungi are species of *Pythium, Rhizoctonia,* and *Fusarium.* For the most part these organisms live on the decaying organic matter in the soil and affect plants only during certain stages, particularly the preemergence seedling stage. Some of these organisms are more aggressive than others, and some crops are more susceptible to certain organisms than to others.

Although the type of organism, its concentration in the soil, and the susceptibility of the host have a considerable effect on the severity of the injury, the environment in which the seed is germinating is also of primary importance. Any condition which interrupts or slows the germination of the seed makes it more susceptible to seed decay. Temperature and soil moisture are the most important environmental factors. With a high-temperature crop, such as the lima bean, any delay in germination caused by low soil temperature usually results in increased seed decay or preemergence damping-off. This is because under certain conditions of low soil temperature the seed-decaying organisms develop faster than the germinating seed (5). High soil moisture is conducive to seed decay for two reasons. It favors many organisms, particularly *Pythium,* which are somewhat aquatic in habit. There is, in addition, an adverse effect on the seed, presumably physiological. It has been noted frequently that even at temperatures optimum for seed germination a poor stand results when heavy rains occur immediately after planting.

Seed-decay, or preemergence damping-off, is controlled quite successfully by coating the seed with a fungicide. The primary purpose served is the protection of the seed and the preemerged seedling from invasion by organisms in the soil. In some instances these fungicides act as disinfestants, killing organisms which occur as contaminants on the surface of the seed before it is planted. Fungicides are usually added to the seed as dusts, but slurries and liquid soaks are also used. Materials currently in common use for control of seed decay in peas, corn, and various types of beans are Arasan, Phygon and Spergon.[3]

Materials And Methods

The various materials used as insecticides and fungicides are listed in Table 1. Dosages given in connection with the experiments are

[3]Schroeder, W. T., and Foster, R. E. Canning crops seed treatment chart, 1950. *New York State Agr. Exp. Station.* (Mimeograph)

TABLE 1.—*Insecticides and fungicides evaluated in the development of a seed treatment to control maggot injury and seed decay.*

Material	Concentration
DDT	50% w.p.*
BHC	50% w.p.
Lindane	25% w.p.
Chlordane	40% w.p.†
Toxaphene	40% w.p.
Dieldrin	25% w.p.
Parathion	15% w.p.
Aldrin	25% w.p.
Arasan	50% dust
Arasan SF	75% w.p.
Spergon	96% dust
Phygon XL	50% w.p.

*w.p. = Wettable powder.
†50% w.p. used in some 1950 tests (Tables 9 and 10) and for storage tests.

the number of ounces of the commercial formulation used per bushel of seed, unless otherwise indicated.

All materials were applied to the seed in combination with an adhesive, methyl cellulose. An adhesive was necessary because the large, smooth-surfaced seeds of beans would not retain sufficient quantities of the materials when applied as dry dusts. Methyl cellulose, being water-soluble, neutral, and physiologically inert, proved to be an ideal sticker. Furthermore, it provided a uniform distribution of the materials over the surface of the seeds. No detrimental effects on germination were observed due to the use of this material.

For the most part, the seeds used for experimentation were those of the large-seeded lima bean, *Phaseolus limensis* (Fordhook Bush type), and the small-seeded or baby lima bean, *P. lunatus* (Henderson or Clark Bush type). Lima beans were used rather than snap beans because they incur greater injury from seed-corn maggot and seed-decaying organisms. The seed used germinated about 85 per cent.

A randomized block design was generally used to test the various treatments, both in the greenhouse and in the field. The number of blocks varied from four to six, depending upon the experiment. In the hand-planted blocks, the number of seeds per plot varied from 25 to 300. In some large-scale experiments, the seed was planted by machine and the emergence records obtained by calculating the number of seeds sown per given length of row, based upon the number of seeds per pound and the rate of sowing.

Evaluation of the seed treatments as a whole, i.e., against both decay organisms and the maggot, was based upon total seedling emergence and number of uninjured or normal plants. The effectiveness of the treatments against maggot injury was further evaluated by an examination of the partially germinated seeds in the soil and of the emerged seedlings. The degree of injury to the seed was deter-

mined by the use of two-row plots, in one of which the seeds were removed from the soil for examination and the other left for emergence counts. On emerged seedlings light injury was manifested by partially consumed primary leaves or tunnelled cotyledons; severe injury, by "baldhead" plants.

Where maggots were reared for the artificial infestation of greenhouse soil, the rearing methods of Ristich and Schwardt were employed (7).

Necessity Of A Fungicide

The idea of seed treatment for control of seed-corn maggot is not new, but the materials first tried were so injurious to the seed that early attempts resulted in failure (3). The new synthetic organic insecticides are much more effective insecticidally than the materials tried earlier, and injury to the seed is not a limiting factor. Nonetheless, the first attempts to use them as seed treatments for maggot control were unsuccessful (7).

Investigations of the possibilities of an insecticidal seed treatment for control of the seed-corn maggot were started at this Station in 1947.[4] The insecticides used were benzene hexachloride (50 per cent wettable powder) and DDT (25 per cent wettable powder), applied at the rate of 4 ounces per bushel of seed. One object of these tests was to determine the effect on maggot control of the method of application of the insecticide to the seed, that is, applied as a seed-coating or mixed with fertilizer placed in the row at the time of planting. Experience had indicated that greater injury by soil microorganisms occurred to seed in the presence of fertilizers, so it was the practice to use a fungicidal seed protectant when fertilizer was placed in contact with the seed. Consequently, the 1947 field tests included treatments consisting of various combinations of the insecticides, method of application, and Arasan. All treatments were applied to baby lima bean seed planted at four different dates. Untreated control plots were also included.

The most significant aspect of the results was that in some of the plots treated with an insecticide only, the stand was poorer than in untreated plots. There was a marked increase in stand in those plots treated with a combination insecticide-fungicide treatment. However, the stand in these was not quite as good as in the plots treated with Arasan alone. There were no significant differences due

[4]The 1947 investigations were carried out by L. A. Carruth, W. T. Schroeder, and M. T. Vittum.

to the method of applying the insecticide. From the results of adding the fungicide it appeared that the application of the insecticide had some adverse effect on the seed, such as to render it more susceptible to seed decay. Furthermore, it seemed likely that the poor results of the first attempts to use these insecticides as seed treatments for seed-corn maggot control were due to the lack of protection against seed decay organisms.

Thus, from the results of these preliminary investigations in 1947, a fungicide appeared to be a necessary component of a seed treatment for seed-corn maggot control. The correctness of this assumption was confirmed repeatedly in later experiments. In addition, control of seed decay was necessary for proper evaluation of the relative effectiveness of the various insecticides.

Results of several years' experimentation with fungicides as protectants from seed decay in beans indicated no substantial preference among the fungicides, Spergon, Phygon, and Arasan. Spergon dust, although conceded to be somewhat the weakest of these, is generally used because it is relatively nonirritating to those handling the product. It also lubricates the seed, causing it to flow easier through the planter.

In combination with insecticides, these fungicides are not equally satisfactory. Preliminary work in 1947 indicated that Arasan, in combination with some of the insecticides, was superior to Spergon. Consequently, it was used in the first field experiments. This superiority was later confirmed in additional experiments with Fordhook 242 lima beans planted in soil heavily infested with seed decay organisms but free from seed-corn maggot (Table 2). Spergon, Phygon, and Arasan were used alone and in combination with chlordane. Untreated seed and seed treated only with chlordane served as controls. Parallel tests were made at two soil temperatures, 60° to 70° F and 70° to 80° F, thus providing conditions for seed decay ranging from severe to mild. Under these conditions, Arasan proved to be superior to the other two materials when used in combination with chlordane, particularly at the lower temperature. Phygon has a tendency to harden the seed coat of beans, thereby hindering or preventing the unfolding of the primary leaves. Plants so affected were weakened and did not emerge as rapidly as did the others and, as a result, were subject to damping-off for a longer period. Thus, although Phygon was as effective as Arasan at the higher soil temperatures, in terms of total emergence it resulted in significantly fewer normal plants.

TABLE 2.—*Performance of several fungicide seed protectants with and without chlordane at two soil temperatures in greenhouse soil infested with damping-off organisms, Geneva, N. Y., 1950.*

Pesticide, ounces per bushel of seed			Seed emergence, per cent†			
			Total		Normal	
Fungicide	Insecticide		60°–70° F	70°–80° F	60°–70° F	70°–80° F
Part A. Comparison of Individual Treatments						
None	None		3	28	0	12
None	Chlordane ,1.0		0	10	0	4
Spergon, 2.0	None		4	71	3	60
Spergon, 2.0	Chlordane, 1.0		1	71	1	62
Phygon, 2.0	None		9	89	4	64
Phygon, 2.0	Chlordane, 1.0		11	83	8	58
Arasan, 2.0	None		38	88	26	84
Arasan, 2.0	Chlordane, 1.0		21	88	13	79
Least difference		(19:1)	7	10	8	9
Required for significance		(99:1)	10	13	11	13
Part B. Comparison of Fungicides‡						
None			2	18	0	8
Spergon			3	71	2	62
Phygon			10	86	6	61
Arasan			29	88	20	82
Least difference		(19:1)	5	7	6	6
Required for significance		(99:1)	7	9	8	9
Part C. Comparison of Insecticides‡						
	None		13	69	8	55
	Chlordane		8	63	5	51
Least difference		(19:1)	4	5	NS	NS
Required for significance		(99:1)	5	6	NS	NS
Part D. Interactions						
Fungicide × insecticide			**	*	*	NS§

*Significant at odds of 19:1.
**Significant at odds of 99:1.
†Based on the average of 4 replicate plots of 40 seeds each.
‡Each figure is an average of all plots where the fungicide or insecticide occurred at the temperatures indicated.
§Not significant.

Spergon was decidedly inferior to Arasan. The use of chlordane without a fungicide resulted in less emergence than from untreated seed.

Additional greenhouse experiments, using lindane instead of chlordane, confirmed the foregoing results. Consequently, Arasan was selected as potentially the most effective fungicidal component of a combination insecticide-fungicide seed treatment for seed-corn maggot control. It was replaced later by Arasan SF which was found to be more readily wettable.

Evaluation Of Insecticides

1947–49 experiments

All of the insecticides tested were not available when these investigations were started in 1947 and, consequently, were added as they were introduced. Those materials which proved unsatisfactory, or obviously inferior to some of the others, were dropped from further tests as this became apparent. Arasan was used in combination with all of the insecticides to control seed decay, the occurrence of which would otherwise interfere with the proper evaluation of the insecticides.

The maggot infestation in 1947 was too low to obtain significant data on the effectiveness of DDT and benzene hexachloride.[5] Both of these insecticides reduced plant emergence. At the concentration used they apparently had a deleterious effect on the seed. In the absence of any consequential maggot infestation, this could not be offset by their action as protectants from maggot injury.

In 1948, lindane, the gamma isomer of benzene hexachloride, was used in place of the benzene hexachloride containing all the isomers. DDT was again included, and chlordane and toxaphene were added. Seed of three bean varieties was treated: Fordhook lima bean, Henderson Bush lima bean, and Tendergreen snap bean. The two row plot system was used so that one row could be dug for maggot injury counts and the other left for plant emergence data.

Consistently low maggot injury occurred in all plots treated with lindane and chlordane (Table 3). DDT and toxaphene failed to prevent serious maggot injury, although some reduction was obtained. Arasan alone had no effect on incidence of maggot injury. As indicated by plant emergence, lindane used at 8.5 ounces had an adverse effect on the lima beans which chlordane did not have. However, the maggot injury counts show that it was as effective as chlordane for control of the maggots. As in 1947, the emergence in the later plantings was much better than that in the first plantings, probably because of more favorable soil conditions for germination and a lower maggot population at the later dates.

Since DDT and toxaphene had shown little potential value as seed-protectants for seed-corn maggot control, they were dropped from further tests and parathion and dieldrin were added in 1949

[5]See footnote 4.

TABLE 3.—*Maggot injury and seedling emergence in three types of bean seed as affected by treatment and planting date, Geneva, N. Y., 1948.**

TREATMENT, OUNCES PER BUSHEL	CROP	MAGGOT INFESTATION, PER CENT, AT FOLLOWING PLANTING DATES				PLANT EMERGENCE, PER CENT, AT FOLLOWING PLANTING DATES			
		May 28	June 4	June 11	June 18	May 28	June 4	June 11	June 18
None	Fordhook	33	36	19	14	22	50	72	85
	Henderson	44	33	7	14	21	18	84	70
	Tendergreen	20	33	1	5	50	32	78	78
Arasan, 4	Fordhook	31	20	12	16	22	49	66	84
	Henderson	53	16	9	11	22	15	81	72
	Tendergreen	20	39	4	6	39	25	83	77
Arasan, 4; Lindane, 8.5	Fordhook	4	0	1	0	8	28	61	75
	Henderson	8	3	1	0	10	9	78	66
	Tendergreen	0	1	0	0	44	43	81	79
Arasan, 4; Chlordane, 5	Fordhook	1	4	0	0	34	42	80	86
	Henderson	7	4	0	1	41	32	96	78
	Tendergreen	3	8	0	1	54	35	88	78
Arasan, 4; DDT, 4.25	Fordhook	21	10	11	0	34	57	76	82
	Henderson	23	3	3	2	29	49	90	79
	Tendergreen	9	14	1	3	32	36	90	72
Arasan, 4; Toxaphene, 5	Fordhook	29	5	1	4	30	64	70	86
	Henderson	7	4	7	5	30	42	91	82
	Tendergreen	4	37	4	0	40	29	82	77

*Based on plots of 25 seeds.

(Table 4). For each insecticide used, there was a treatment with and without Arasan.

Unfortunately, the maggot infestation was low in the 1949 season, and no significant data were obtained on the effectiveness of the insecticides for maggot control. However, it became further apparent that these insecticides had an adverse effect on seed germination. When the insecticides were applied to the seed without a fungicide, the seedling emergence was less than that in the plots which had received no treatment at all (Table 4). This adverse effect could be ameliorated by the addition of Arasan. It should be noted that when the dosage of lindane was reduced from the 8.5 ounces per bushel rate used in 1948 to 3.8 ounces in 1949, lindane caused no more injury to the seed than did chlordane.

TABLE 4.—*Seedling emergence from Fordhook 242 lima bean seed as affected by treatment and planting date, Geneva, N. Y., 1949.*

Treatment ounces per bushel			Emergence of normal plants, per cent*	
Insecticide	Fungicide		Planted May 21	Planted June 4
None	None		28	46
None	Arasan, 2.0		44	78
Lindane, 3.8	None		7	32
Lindane, 3.8	Arasan, 2.0		44	72
Chlordane, 4.8	None		4	54
Chlordane, 4.8	Arasan, 2.0		54	79
Dieldrin, 3.8	None		5	36
Dieldrin, 3.8	Arasan, 2.0		51	71
Parathion, 6.5	None		4	42
Parathion, 6.5	Arasan, 2.0		38	76
DDT, 3.0	Spergon, 2.4		21	76
Least difference		(19:1)	10	7
Required for significance		(99:1)	13	9

*Based on the average of four replicate plots of 90 seeds each.

1950 experiments

The investigations of 1947–49 showed the effectiveness and potentialities of the use of insecticidal seed treatments for seed-corn maggot control. However, the dosages of the insecticides, because of adverse effects on the seed, were still too high for maximum effectiveness, especially in the early plantings. Consequently, in 1950, greenhouse and field tests were conducted to determine the effect of chlordane dosages on plant emergence and maggot control. The object of these tests was to detemine what concentrations would give effective maggot control with the least reduction in seedling emergence. Although the seed in the field experiments was treated with

Arasan, the soil temperature at the time of planting was so low that generally poor emergence resulted (Table 5). The two-row plot system was used so that maggot injury could be evaluated separately.

TABLE 5.—*Effect of varied chlordane dosage on seedling emergence and seed-corn maggot injury in Fordhook 242 lima bean seed planted May 7, 1950, Geneva, N. Y.*

OUNCES CHLORDANE (ACTUAL) PER BUSHEL	SEEDLING EMERGENCE, PER CENT*		MAGGOT INJURY, PER CENT†
	Total	Normal	
0	2	1	92
0.04	15	10	56
0.2	16	13	49
0.4	18	16	27
1.0	18	16	23
1.9	1	1	0
Least difference (19:1)	10	9	20
Required for significance (99:1)	13	12	25

*Based on the average of four replicate plots of 75 seeds each.
†Based on total emergence.

Complete maggot control was obtained with 1.9 ounces of chlordane. However, examination of the field data (Table 5) indicates that it would not be practical to attempt 100 per cent maggot control because of the plant injury which would result at the dosages necessary. In the greenhouse tests (Table 6), where the incidence of seed decay was considerably lower, there was much less difference between plant emergence at 1.9 and 1.0-ounce dosages.

Figure 3 shows graphically the effect on maggot injury of varying chlordane dosages in the field and in the greenhouse. A sigmoid dosage mortality curve would not be expected because control was not based directly on the number of maggots killed but on the number of uninjured plants. The difference between the two curves probably results from the more even distribution of the maggot infestation in the greenhouse. In the field there appeared to be only slight differences in plant injury and maggot control between 1 ounce and 0.4 ounce of chlordane and dosages lower than these. This indicated that a dosage of between 0.4 and 1.0 ounce of actual chlordane per bushel would probably be the most effective for use in a seed treatment. These data (Tables 5 and 6) afford an explanation of the poor stands obtained with the insecticide dosages used in the 1948–49 experiments. The amount of actual toxicant, 1.9 ounces per bushel, was the same as that in the 1949 tests where 4.8 ounces of 40 per cent chlordane were used per bushel. The dosages used in 1947 and 1948 were still greater than this.

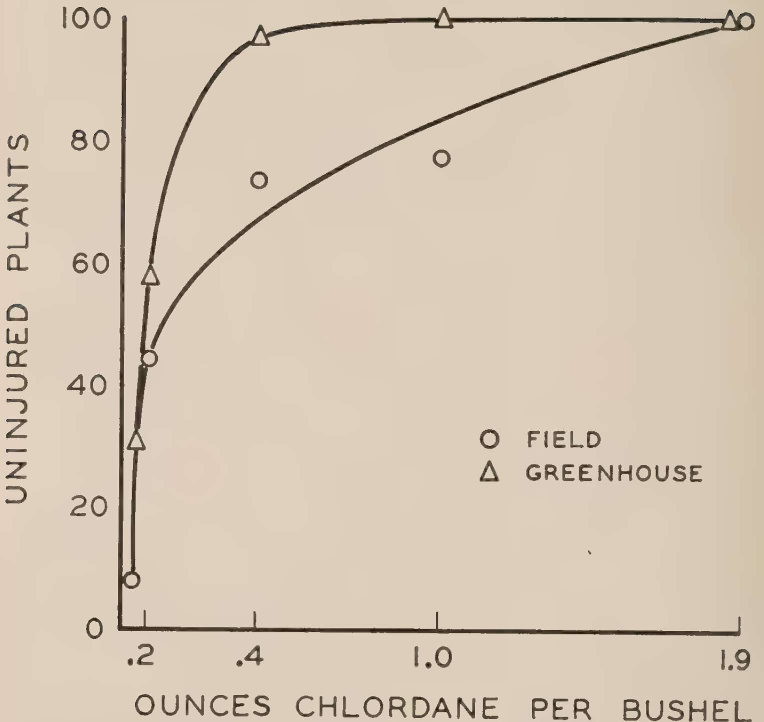

Fig. 3.—Dosage-response curves showing effect of chlordane (actual toxicant) in seed-corn maggot control under field and greenhouse conditions.

TABLE 6.—*Seedling emergence and maggot injury in Fordhook 242 lima bean seed planted in greenhouse soil artificially infested with seed-corn maggot and treated with varied chlordane dosage, 1950.*

CHLORDANE (ACTUAL) PER BUSHEL, OUNCES	SEEDLING EMERGENCE, PER CENT*		MAGGOT INJURY, PER CENT†	
	Total	Normal	Emerged	Unemerged
0	42	18	59	78
0.04	60	50	17	69
0.2	65	62	4	7
0.4	60	60	12	0
1.0	68	68	0	0
1.9	75	75	0	0

*Based on four replicate plots of 10 seeds each.
†Based on number of plants emerged or unemerged.

In 1950 only the most promising materials (aldrin, chlordane, dieldrin, and lindane) were tested. The dosages were considerably less than in 1949 (Table 7). The results showed that the reduced dosages

did not diminish the protective value against the seed-corn maggot, although the maggot infestations in the first two plantings were the heaviest encountered during the four years. Moreover, less insecticidal injury occurred to the seed with these reduced dosages.

TABLE 7.—*Emergence of normal seedlings from Fordhook 242 lima bean seed as affected by treatments and planting dates, Geneva, N. Y., 1950.*

TREATMENT, OUNCES PER BUSHEL			EMERGENCE OF NORMAL PLANTS, PER CENT*			
Insecticide	Fungicide		May 6	May 15	May 22	June 13
	Part A. Comparison of Individual Treatments					
None	None		0	0	9	41
None	Arasan, 2.0		0	5	8	44
Dieldrin, 2.5	None		13	41	17	51
Dieldrin, 2.5	Arasan, 2.0		21	76	37	74
Aldrin, 2.5	None		7	30	14	32
Aldrin, 2.5	Arasan, 2.0		21	79	30	67
Lindane, 2.0	None		18	42	16	53
Lindane, 2.0	Arasan, 2.0		20	79	26	70
Chlordane, 1.6	None		10	21	9	35
Chlordane, 1.6	Arasan, 2.0		19	62	30	67
Least difference		(19:1)	3	4	3	5
Required for significance		(99:1)	4	6	4	7
	Part B. Comparison of Insecticides †					
None			0	3	8	42
Dieldrin, 2.5			17	58	27	63
Aldrin, 2.5			14	54	22	49
Lindane, 2.0			19	61	21	61
Chlordane, 1.6			14	42	19	51
Least difference		(19:1)	3	4	3	6
Required for significance		(99:1)	4	6	4	8
	Part C. Comparison of Fungicides †					
	None		10	27	13	42
	Arasan, 2.0		16	36	26	64
Least difference		(19:1)	2	3	1	4
Required for significance		(99:1)	3	4	2	5
	Part D. Interactions					
Insecticide × fungicide			**	**	**	**

*Based on the average of 6 replicate plots of 150 seeds each.
†Each figure represents the average from all plots where the insecticide or fungicide occurred at the planting date indicated.
**Significant at odds of 99:1.

All the materials gave good control in all of the 1950 field experiments (Figs. 4 and 5, Tables 7, 9, and 10) except in two plantings of one experiment (Table 7). In the May 6 planting the stands were poor compared with those of the succeeding plantings, although treated seed gave much better stands than did untreated seeds. A

Fig. 4. — Plots showing effect of seed treatments; (4) dieldrin plus Arasan, (2) Arasan alone, (1) no treatment, (5) dieldrin alone, (9) lindane alone, (next row) lindane plus Arasan. 1950.

Fig. 5. — Lima bean stand obtained with treated and untreated seed. In the two untreated rows (center) each stake marks a maggot-injured plant. 1950.

number of seeds were dug in each treatment to determine the cause. It was found that the low emergence was due to seed decay (Table 8). Although all of the untreated seed was injured by maggots, only

a very few of the treated seeds were injured. The high incidence of seed decay can probably be ascribed to the unusually long period (16 days) between planting and initial emergence. Low emergence in the May 22 planting was due to some unaccountable factor.

TABLE 8.—*Seed-corn maggot injury and seed decay in Fordhook 242 lima bean seed removed from soil 15 days after planting as affected by seed treatments, Geneva, N. Y., 1950.*

TREATMENT, OUNCES PER BUSHEL		NUMBER SEED EXAMINED	NUMBER SEED DECAYED	NUMBER SEED INJURED BY MAGGOT
Insecticide	Fungicide			
None	None	12	12	12
None	Arasan, 2.0	12	12	12
Dieldrin, 2.5	None	13	6	2
Dieldrin, 2.5	Arasan, 2.0	14	10	5
Aldrin, 2.5	None	14	11	0
Aldrin, 2.5	Arasan, 2.0	12	7	2
Lindane, 2.0	None	10	6	3
Lindane, 2.0	Arasan, 2.0	11	7	2
Chlordane, 1.6	None	14	12	4
Chlordane, 1.6	Arasan, 2.0	16	11	3

In 1950, field-scale experiments were conducted with Clark's Bush lima bean.[6] One of the primary objects of these tests was to determine if the seed treatment would make possible earlier planting than is customary. Two series of plantings were made. In one of these the seed was hand-planted (Table 9); in the other, it was mechanically planted (Table 10). In the mechanically planted series,

TABLE 9.—*Seed-corn maggot injury and seedling emergence in Clark's Bush lima bean seed as affected by treatment and planting date, Geneva, N. Y., 1950.*

TREATMENT, OUNCES PER BUSHEL		NORMAL PLANTS EMERGED, PER CENT*				MAGGOT INJURY, PER CENT†			
Insecticide	Fungicide	May 13	May 21	June 7	June 14	May 13	May 21	June 7	June 14
None	None	23	30	54	55	33	27	34	23
None	Arasan, 2.0	35	27	56	67	30	21	34	17
Chlordane, 0.83	None	43	52	72	43	15	10	8	2
Chlordane, 0.83	Arasan, 2.0	61	56	77	78	17	16	10	6
Lindane, 0.83	None	52	62	75	37	7	4	2	0
Lindane, 0.83	Arasan, 2.0	72	78	82	79	7	4	3	0
Least difference	(19:1)	9	8	8	5	7	6	7	4
Required for significance	(99:1)	12	10	11	7	9	8	9	6

*Based on the average of four replicate plots of 300 seeds each.
†Based on total emergence.

[6]The writers wish to acknowledge the cooperation of the Curtice Bros. Canning Company of Rochester, N. Y., which provided the seed, land, and cultural care for some of these field tests.

there were only two plantings, made early in the season. Only two insecticides, chlordane and lindane, were used.

Excellent control was obtained in the plots where the combination insecticide-fungicide treatments were applied. As can be observed from the untreated plots, the maggot infestation in the mechanically planted series (Table 10) was heavier than in that planted by hand

TABLE 10.—*Seed-corn maggot injury and plant emergence in Clark's Bush lima bean seed as affected by treatment and planting date, Geneseo, N. Y., 1950.*

Treatment, ounces per bushel		Normal plants, per cent*		Maggot injury, per cent†	
Insecticide	Fungicide	May 16	May 23	May 16	May 22
None	None	7	35	47	32
None	Arasan, 2.0	24	41	45	20
Chlordane, 0.83	None	20	50	10	8
Chlordane, 0.83	Arasan, 2.0	52	57	13	7
Lindane, 0.83	None	31	60	6	6
Lindane, 0.83	Arasan, 2.0	56	75	4	4
Least difference	(19:1)	8	13	9	6
Required for significance	(99:1)	11	18	12	8

*Based on amount of seed sowed per 100 feet of row, average of six replicates.
†Based on total emergence.

(Table 9). Consequently, better control was obtained in the latter. The results of these experiments support previous assumptions and findings and are especially significant because of their large scale. It can be seen that the high degree of control in these experiments was obtained with very low dosages of the pesticides, lindane at 0.2 ounce actual toxicant per bushel, chlordane at 0.42 ounce, and Arasan at 1.0 ounce.

These experiments demonstrate further that by treating the seed, lima beans can be planted in this area at a much earlier date than would otherwise be possible. In one of these field tests (Table 9), adequate stands were obtained from treated seed planted May 13, whereas it was not until the June 7 planting that suitable stands were obtained from untreated seed. Figure 6 shows the relationship of planting date to stand, from untreated seed and from seed treated with lindane and Arasan. As usual, the lower stands in the untreated plots at the earlier planting dates were primarily due to less favorable conditions for germination, resulting in longer exposure to seed decay organisms and maggots. Table 11 shows the relationship of planting date and mean soil temperature 1½ inches below the surface to time required for emergence.

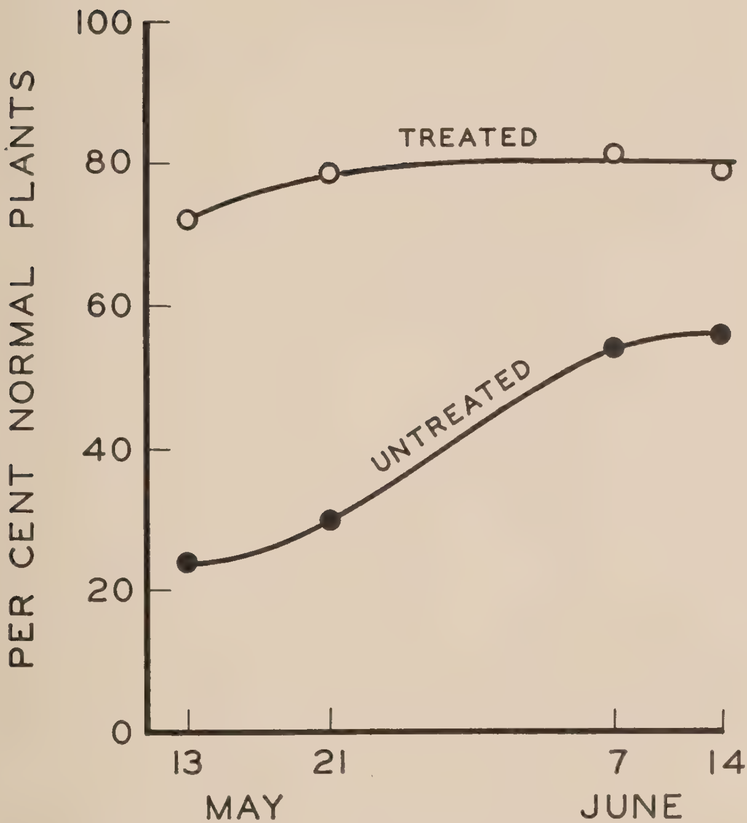

Fig. 6.—Relation of planting date to seedling emergence from treated and untreated lima bean seed.

There has been some question as to whether earlier planting of lima beans would result in appreciably earlier maturity. Maturity counts, based on the percentage of white seeds after blanching, were made in some of the 1950 plantings. In those planted on May 16 and harvested September 5, 60 per cent of the seed turned white after blanching; in the May 23 planting, harvested September 6, 19 per cent turned white. Table 12 presents further evidence that earlier planting leads to earlier maturity.

TABLE 11.—*Relation of planting date and soil temperature to seedling emergence of treated and untreated seed in two experiments, Geneva, N. Y., 1950.*

PLANTING DATE	DAYS FOR EMERGENCE	MEAN SOIL TEMPERATURE, °F †	EMERGENCE OF NORMAL PLANTS, PER CENT* Treated	Untreated
		Experiment No. 1 ‡		
May 13	13	62.2°	72	23
21	9	65.7°	78	30
June 7	7	71.0°	82	54
14	8	67.2°	79	55
		Experiment No. 2 §		
May 6	16	59.1°	20	0
15	13	65.8°	79	0
22	9	70.3°	26	9
June 13	9	71.8°	70	41

*Based on the average of six replicate plots.
†At 1½ inches below surface.
‡Seed treated with lindane, 2 ounces per bushel and Arasan, 2 ounces per bushel.
§Seed treated with lindane, 0.83 ounce per bushel and Arasan, 2 ounces per bushel.

TABLE 12.—*Influence of planting date and length of growing season on maturity of lima beans, Geneva, N. Y., 1951.*

VARIETY	PLANTING DATE	HARVEST DATE	GROWING SEASON, DAYS	WHITE SEEDS, PER CENT
Clark's Bush	May 14	Aug. 23	101	12
Clark's Bush	May 28	Sept. 5	100	4
Clark's Bush	June 12	Sept. 12	91	0.5
Fordhook 242	May 18	Aug. 28	102	13
Fordhook 242	June 7	Sept. 5	90	3

Treatment Of Seed Other Than Lima Beans

Red kidney beans were treated with a slurry containing chlordane and Arasan, both applied at the rate of 2 ounces per bushel of seed. In a heavy maggot infestation, the untreated plots showed 55 per cent injured plants (2,874 plants examined), whereas the treated plots had only 13 per cent injury (2,644 plants examined). The effectiveness of treating snap beans (Tendergreen variety) was shown in Table 3.

In cooperative tests with various commercial organizations, sweet corn was treated with 2 ounces of Arasan per bushel in combination with varying dosages of chlordane, *viz.*, 0.5, 1.0, and 1.5 ounces per bushel. Emergence improved with increasing chlordane dosage for all the sweet corn varieties except for a high quality inbred variety. For this variety best results were obtained with 1 ounce per bushel.

To date, seed growers have treated a considerable amount of stock seed with 1.3 ounces of Arasan SF plus 1 ounce of chlordane or lindane per bushel, with satisfactory results.

Excellent control of seed-corn maggot was obtained in several varieties of squash by treating the seed with 2 ounces of Arasan plus 1.2 ounces of chlordane per bushel. Untreated seed and seed treated with Arasan only were completely destroyed in these tests and had to be replanted. All 200 hills of treated seed emerged normally.

Insecticides applied to peas in combination with the standard Spergon treatment increased emergence over that from untreated seed and seed treated with Spergon only (Table 13). Dieldrin and chlordane were somewhat better than DDT. Further tests on peas are obviously needed.

TABLE 13.—*Emergence of Thomas Laxton pea seed as affected by seed treatment, Geneva, N. Y., 1950.*

Treatment, ounces per bushel			Seedling emergence, per cent*
Insecticide	Fungicide		
None	None		62
None	Spergon, 2.0		69
DDT, 2.0	Spergon, 3.0		72
Chlordane, 2.0	Spergon, 2.0		76
Dieldrin, 2.0	Spergon, 2.0		79
Least difference		(19:1)	6
Required for significance		(99:1)	8

*Based on four replicate plots of 200 seeds each.

Storage Of Treated Seeds

To make maximum practical use of seed treatment, it would be desirable to treat the seed at the time of harvesting and store it in the treated condition until the following spring. This brought up the question of possible adverse effects due to storage. There appeared to be two possible sources of deleterious effects from long periods (several months or more) of storage of treated seed. First, it was possible that the pesticides might lose their effectiveness during such a period. The other possibility was that the presence of these pesticides on the seed for long periods of time might have a phytotoxic effect.

All of the seed used in these tests was from one lot of Clark's Bush lima bean seed, harvested in 1949, and placed in storage on October 26, 1950. Part of it was held at a storage temperature of 40° to 50° F and part at 70° to 80° F. Some of the seed from each temperature

lot was treated at the time of placing it in storage with four treatments, *viz.,* Arasan and lindane, Arasan and chlordane, Arasan and dieldrin, and Arasan alone. On May 10, 1951, another part of this seed was treated with the same four treatments. Both storage temperatures were again represented. Enough seed was left untreated so that there would be available as checks seed held at both temperature ranges.

The first plantings from this stored seed were made in the field in the spring of 1951 at three planting dates, May 14, May 28, and June 12. All plantings were adjacent to each other within the same field. Thus, these plantings included seed which had been treated 7 months before (October), seed treated immediately prior to planting (May 10), and untreated seed. A second planting was made in the greenhouse on December 13, 1951. This planting constituted a comparison between seed which had been treated 58 weeks previously (October, 1950), seed treated 31 weeks earlier (May, 1951), and untreated seed for each of these periods. In the greenhouse each treatment from each storage temperature was planted in pasteurized soil and in non-pasteurized soil. The non-pasteurized soil contained seed decay organisms but no maggots.

Results of field tests

The experiment was designed to permit analysis of the effect, singly and in combination, of the factors involved. These factors were the chemicals, length of storage, storage temperature, and planting date. Evaluation was based on total emergence, normal plants, and evidence of maggot injury on emerged plants. The detailed data are given in Table 14 and are summarized in Table 15.

Injury from seed-corn maggot was greatest in the first planting and decreased with the later plantings (Fig. 7). Seed decay was least in the first planting and greatest in the last planting. The high incidence of seed decay in the last planting was probably due largely to heavy rains during the two days immediately after planting. In the first two plantings, there was little rain until after emergence had started. Consequently, in these plantings, where maggot injury was greatest, the insecticide-fungicide combinations resulted in a higher percentage of normal plants than did treatment with Arasan alone. In the last planting, where seed decay was the principal source of injury, there were no differences in the percentage of normal plants between the combination treatments and Arasan alone.

TABLE 14. *Seedling emergence and maggot injury in treated Clark's Bush lima bean seed as affected by period of storage and storage temperature, Geneva, N. Y., 1951.*

Treatment, ounces per bushel		Date treated	Storage temperature, °F	Seedling emergence and maggot injury at following planting dates*								
				May 14			May 28			June 12		
Insecticide	Fungicide			T	N	M	T	N	M	T	N	M
Lindane, 1.0	Arasan SF, 1.3	Oct. 26, 1950	40°–50°	76	67	11	64	64	1	33	32	2
Lindane, 1.0	Arasan SF, 1.3	Oct. 26, 1950	70°–80°	71	65	9	69	68	1	42	42	0
Lindane, 1.0	Arasan SF, 1.3	May 10, 1951	40°–50°	74	66	8	69	68	1	25	25	0
Lindane, 1.0	Arasan SF, 1.3	May 10, 1951	70°–80°	71	65	8	62	60	2	29	29	0
Dieldrin, 1.0	Arasan SF, 1.3	Oct. 26, 1950	40°–50°	80	73	8	69	68	1	41	41	0
Dieldrin, 1.0	Arasan SF, 1.3	Oct. 26, 1950	70°–80°	73	66	9	70	69	1	35	35	1
Dieldrin, 1.0	Arasan SF, 1.3	May 10, 1951	40°–50°	76	71	7	68	67	2	49	49	0
Dieldrin, 1.0	Arasan SF, 1.3	May 10, 1951	70° 80°	74	68	10	68	68	1	35	34	1
Chlordane, 1.0	Arasan SF, 1.3	Oct. 26, 1950	40°–50°	76	66	12	72	71	1	40	40	0
Chlordane, 1.0	Arasan SF, 1.3	Oct. 26, 1950	70°–80°	70	62	12	64	60	4	29	29	1
Chlordane, 1.0	Arasan SF, 1.3	May 10, 1951	40°–50°	74	66	10	60	52	5	35	35	0
Chlordane, 1.0	Arasan SF, 1.3	May 10, 1951	70°–80°	70	60	15	68	64	5	43	43	1
None	Arasan SF, 1.3	Oct. 26, 1950	40°–50°	77	57	26	71	54	24	44	40	10
None	Arasan SF, 1.3	Oct. 26, 1950	70°–80°	64	50	23	69	52	29	37	32	14
None	Arasan SF, 1.3	May 10, 1951	40°–50°	78	61	21	69	56	19	42	36	12
None	Arasan SF, 1.3	May 10, 1951	70°–80°	66	52	21	70	53	26	36	30	12
None	None	Oct. 26, 1950	40°–50°	57	38	32	42	34	19	11	10	1
None	None	Oct. 26, 1950	70°–80°	48	32	32	45	36	19	5	4	9
None	None	May 10, 1951	40°–50°	65	46	28	52	42	21	15	15	3
None	None	May 10, 1951	70°–80°	52	40	24	45	39	14	5	5	1
Least difference	(19:1)			6	7	7	10	10	7	15	14	6
Required for significance	(99:1)			7	9	10	14	14	9	19	19	8

*Based on the average of six replicate plots of 100 seeds each. T = Per cent total emergence; N = Per cent normal plants; M = Per cent maggot injury based on total emergence.

TABLE 15.—*Summary of the effects of pesticides, storage periods, and storage temperature on emergence and maggot injury in Clark's Bush lima bean seed (combination of three planting dates from Table 14).*†

Treatments		Total emergence, per cent	Normal plants, per cent	Maggot injury, per cent
Part A. Comparison of Seed Treatments				
Lindane + Arasan SF		57.0‡	54.3	3.6
Dieldrin + Arasan SF		61.5	59.0	3.4
Chlordane + Arasan SF		58.3	54.0	5.6
Arasan SF only		60.4	47.6	19.6
None		36.9	28.6	17.0
Least difference required	(19:1)	3.1	3.1	1.9
For significance	(99:1)	7.7	4.1	2.5
Part B. Comparison of Storage Treatments				
Stored, treated		54.8	48.6	13.1
Stored, not treated		54.9	48.8	11.6
Least difference required	(19·1)	NS	NS	NS
For significance	(99:1)			
Part C. Comparison of Storage Temperatures				
Stored at 40–50° F.		56.8	50.3	11.9
Stored at 70–80° F.		52.9	47.1	12.7
Least difference required	(19:1)	2.0	2.0	NS
For significance	(99:1)	2.6	2.6	
Part D. Interactions				
Seed treatment × storage temperature		NS§	NS	NS
Seed treatment × storage treatment		NS	NS	NS
Storage temperature × storage treatment		NS	NS	NS
Seed treatment × storage temperature × storage treatment		*	*	NS

*Significant at odds of 19:1.
†Data from untreated plots not included in the analysis of the factorial experiment.
‡Each figure represents the average of all plots where the pesticide treatment occurred.
§Not significant.

Storage of treated seed at the lower temperature, 40° to 50° F, for 26 weeks before planting had no adverse effect on the vigor of the seed nor on the pesticidal value of the treatment. The higher storage temperature (70° to 80° F) reduced the vigor of the seed but not the pesticidal value of the treatments. There was no indication that the pesticides had any adverse effects on the vigor of the seed. The lack of any significant interaction among pesticides, length of storage period, and storage temperature also indicates that the high storage temperature was the only detrimental factor in this experiment. The significant interaction between planting date and pesti-

Fig. 7.—Stand of lima beans showing effect of fungicide alone under conditions of low maggot infestation; (8) no treatment, (10) Arasan alone, (3) dieldrin plus Arasan. 1951.

cides results from the variations in maggot injury and seed decay among the plantings. For example, the difference between Arasan alone and an Arasan-insecticide combination would be greater when seed-corn maggot injury was predominant than when seed decay was the more prevalent.

Both the average total emergence and the number of normal plants were significantly higher in the Arasan-dieldrin plots than in either of the other two combination treatments. Arasan-chlordane was least effective. However, these differences among the combination treatments are small from the practical standpoint. The average total emergence of the plots treated with Arasan alone was as high as in plots treated with an insecticide and Arasan, but the number of normal plants was lower. This difference between total and normal plants was due to the many maggot-injured plants, such as baldheads, which emerged but did not result in normal plants. Maggot injury was significantly greater in plots treated with Arasan only than in untreated plots, but this difference resulted entirely from the method of taking data. Maggot injury was based on counts made from emerged plants only. In the untreated plots, the lack of protection against seed decay resulted in much lower emergence.

TABLE 16.—*Seedling emergence from treated Clark's Bush lima bean seed in pasteurized and non-pasteurized soil as affected by pesticides, storage period, and storage temperature, Geneva, N. Y., 1951.**

TREATMENT, OUNCES PER BUSHEL		STORAGE TEMPERATURE, 40°–50°F				STORAGE TEMPERATURE, 70°–80°F				AVERAGE
		31 weeks storage, seedling emergence, per cent		58 weeks storage, seedling emergence, per cent		31 weeks storage, seedling emergence, per cent		58 weeks storage, seedling emergence, per cent		
Insecticide	Fungicide	Infested	Pasteurized	Infested	Pasteurized	Infested	Pasteurized	Infected	Pasteurized	
Lindane, 1.0	Arasan SF, 1.3	58	94	63	91	21	62	29	58	60
Dieldrin, 1.0	Arasan SF, 1.3	72	95	48	100	27	59	12	59	59
Chlordane, 1.0	Arasan SF, 1.3	60	95	55	97	30	65	16	59	60
None	Arasan SF, 1.3	71	92	80	92	26	63	22	62	64
None	None	1	95	1	93	0	52	1	68	39
Average		52	94	49	95	21	60	16	61	
Length of storage average		73		72		40		38		
Storage temperature average		72				39				

*Percentages based on three replicate plots of 40 seeds each.

Results of greenhouse tests

In these tests the various treatments were again evaluated on the basis of total emergence and number of normal plants. Since the data on normal plants paralleled that on total emergence, differing only in that the percentage was usually somewhat lower, only the data on total emergence are presented and discussed.

The most striking result of this experiment was the marked reduction in vigor of the seed stored at the higher temperature, 70° to 80° F (Table 16). Storage at this temperature reduced emergence in all treatments. Since a comparable reduction did not occur at the lower temperature (40° to 50° F), this reduction was undoubtedly due to the high temperature and not to the presence of the pesticides on the seed. In pasteurized soil there was no difference in emergence between untreated and treated seed stored for the same period and at the same temperature. However, untreated seed stored at the lower temperature gave much higher emergence than that stored at the higher temperature. Within either of the temperature ranges, there were no significant differences due to length of time in storage, that is, between 31 and 58 weeks.

The significant interaction between storage and seed treatment (Table 18) is due to the fact that seed treated with Arasan and lin-

TABLE 17.—*Summary of factorial analysis of effects of storage, storage temperature, and pesticides on total emergence of Clark's Bush lima bean seed in pasteurized and non-pasteurized greenhouse soil (from Table 16).*

FACTORS	D F	MEAN SQUARES†
Soils	1	8875.4**
Storage†	1	12.1
Seed treatment	4	371.7**
Storage temperature	1	5253.7**
Storage × seed treatment	4	25.7*
Storage × storage temperature	1	0.7
Storage temperature × seed treatment	4	83.4**
Storage × seed treatment × storage temperature	4	12.4
Soils × storage	1	24.1
Soils × seed treatment	4	358.8**
Soils × storage temperature	1	0.6
Soils × storage × seed treatment	4	30.0*
Soils × storage × storage temperature	1	1.2
Soils × seed treatment × storage temperature	4	95.4**
Soils × storage × seed treatment × storage temperature	4	14.0
Error	76	9.4

*Significant at odds of 19:1.
**Significant at odds of 99:1.
†Storage refers to the period during which the treated seed was stored.

dane showed a higher emergence for the longer storage period, whereas for all the other treatments emergence was higher at the shorter storage period. Since this interaction was not significant when the treatments were evaluated on the basis of normal plants, it probably has no practical significance. Further tests with still longer storage periods may clarify this question. The significant interactions between seed treatment, soils, and storage temperature can be accounted for by the difference in emergence of untreated seed in pasteurized and infested soils.

Directions For Treatment Of Seed

In order to make the fungicide and insecticide adhere to the seed, it is necessary to use a sticker. A 4 per cent methyl cellulose (Methocel) solution meets this need satisfactorily. Suspension of the insecticide and fungicide in this solution facilitates the spreading of these materials over the surface of the seed. The recommended insecticidal and fungicidal materials, and the amount of these and Methocel to be used per bushel of seed, are given in Table 18.

TABLE 18.—*Treatment per bushel of bean seed.*

FUNGICIDE	INSECTICIDE	STICKER
Arasan SF, 1.3 oz.	Lindane (25% W.P.)*, 1 oz., or Dieldrin (25% W.P.), 1 oz. or Aldrin (25% W.P.), 1 oz. or Chlordane (50% W.P.), 1 oz.	4% Methocel, ½ pt.†

*W. P. = Wettable powder.
†Methocel (15 c.p.s.), Dow Chemical Company, Midland, Mich.

The method of preparing the slurry treatment may be varied. One way is to prepare the Methocel solution separately and add the insecticide and fungicide at the time the seed is treated.

To prepare 1 gallon of a 4 per cent Methocel solution:

1. Add ⅓ pound of Methocel to 1 quart of hot water, stir and allow to soak for 20 to 30 minutes.

2. Add 3 quarts of water and stir until a smooth mixture is obtained.

3. Allow to cool with occasional stirring and store in containers with tight-fitting lids if not used immediately.

4. Thoroughly mix the proper amounts of insecticide and fungicide (Table 19).

5. Add this dry mixture to the Methocel solution, and stir until evenly distributed.

Another method of preparing the slurry is to add the powdered Methocel directly to the insecticide and fungicide. This dry mixture is then slowly added to the required volume of water and stirred until a smooth dispersion is obtained. Before applying to the seed, allow the slurry to stand for at least 1 hour so that the Methocel will be completely dissolved. To treat 1 bushel of seed by this method, mix 1/3 ounce of powdered Methocel with the required amounts of insecticide and fungicide (Table 18).

Commercially prepared slurries, which can be applied directly to the seed, are also available. As much as 200 to 300 pounds of bean seed can be treated efficiently in one lot by one or two men. Place the seed in a flattened pile on a clean, smooth floor or tarpaulin and distribute the slurry over the seed. The slurry should then be thoroughly mixed with the seed by raking or shovelling. This is continued until the seed is dry. With adequate air circulation, a batch of seed can be treated in 15 or 20 minutes. Treated seed should not be stored at high temperatures or a marked reduction in germination and emergence will result. Some New York seedsmen now sell bean seed already treated.

Discussion

The seed treatment described here has already been used by some growers and seedsmen, and the acreage planted with treated seed is rapidly increasing. In the absence of serious infestations of seed-corn maggot and seed decay organisms, at least 50 to 60 per cent stands are obtained from untreated seed in western New York. Stands may be much poorer than this when the maggot and decay organisms are abundantly present, which is frequently the case. In such instances, reseeding is the only practical alternative. Although the probability of getting an adequate stand increases as the season progresses, the results are always uncertain with untreated seed. However, the use of a combination insecticide-fungicide introduces a high degree of certainty in obtaining satisfactory stands, even at early planting dates (Tables 8 and 9).

The practicability of the treatment is greatly enhanced by its cheapness and by the simplicity of the process of applying the pesti-

cides to the seed. Storage experiments with treated seed indicate that seedsmen can treat seed at the most convenient time after harvesting.

The germination rate of bean seed depends to a large extent upon soil temperature. Seed planted in cool soil is likely to incur greater injury from seed-corn maggot and decay organisms because it will be exposed for a longer time. It would be expected that as the season progresses and soil temperatures rise these pests would cause increasingly less damage to the seed. This tendency was evident throughout the five years of these investigations. With respect to planting date, the difference in stands from treated and untreated seed becomes much less marked as the season progresses. There were occasional exceptions where the stand in later plantings was no better than in earlier plantings. Such an occurrence could be caused either by temporary late cool weather or by heavy rains immediately after planting. These rains might lower the soil temperature or produce a soil moisture content higher than that favorable for germination.

In the complete absence of maggots and seed decay, the recommended treatment would cause about 5 per cent reduction in stand. In actual practice, there is nearly always some loss due to decay or maggot injury. The protection obtained from the seed treatment more than compensates for the small amount of injury due to treatment. Part of this injury is due to the fungicide but more to the insecticide. The exact nature of this insecticide injury is unknown. In the first experiments (1947–48), when relatively large amounts of the insecticides were applied to the seed, the reduction in emergence was very marked. It is not likely that the injury was directly due to an injurious effect of the insecticide, since increased stands resulted from adding the fungicide. The mitigating influence of the fungicide suggests the possibility that the insecticides render the seed more susceptible to decay by weakening it. Another possibility is that the germination rate is inhibited so that the seed is exposed to the action of decay-producing organisms for a longer time.

It does not appear that the increased stands resulting from seed treatment will necessitate a change in seeding rate from that ordinarily used in New York. Tests have been made in Pennsylvania (4) to determine the optimum row-spacing and spacing of plants within rows. Higher yields per acre were obtained with a 2-inch spacing than with 4- or 8-inch spacings when the rows were 20 or 30 inches apart. Such stands would be denser than those resulting from the usual rate of seeding in New York.

In regard to cultural practices, there is also the question of the most desirable planting time. Considerable attention was given to the possibility of planting earlier than June because the growing season in western New York is somewhat short for lima beans. When it was shown that adequate stands could be obtained in early plantings, the possibility was suggested that earlier planting might not result in appreciably earlier maturity. However, the data presented in Table 12 show that this was not the case. These findings are supported by the work of Clore (2). In addition to the desirability of having a longer growing season, early planting will enable canning and freezing organizations to arrange their operations more conveniently. For example, succotash packers can adjust their plantings so that lima beans and sweet corn will mature at the same time.

Summary

The development of a combination insecticide-fungicide seed treatment for control of seed-corn maggot and seed decay organisms in beans is described. Adequate stands were not obtained when the seed treatment consisted only of an insecticide. Conversely, a fungicide alone was not satisfactory.

Aldrin, chlordane, dieldrin, and lindane gave satisfactory results as seed treatments for seed-corn maggot control. DDT, parathion, and toxaphene did not. In combination with insecticides, Arasan was more satisfactory than Spergon or Phygon as a seed treatment for beans. To prevent insecticidal injury to the seed, it was necessary to reduce the dosage to a minimum. For example, in the 1948 tests, 5 ounces of chlordane were applied per bushel of seed; in 1950, 1 ounce. The exact nature of the insecticide injury is not known. However, it was ameliorated by the use of a fungicide with the insecticide.

Beans may be planted earlier than has been customary in western New York if the seed is treated. Good stands were obtained from plaintings made as early as May 13. Satisfactory stands were not obtained from plantings earlier than this.

A seed treatment based on the necessity of including both an insecticide and a fungicide is recommended, particularly for use on beans and corn. Data are also presented concerning the uses of this treatment on squash and peas. Directions are included for preparing the treatment mixture and applying it to the seed. The recommended treatment per bushel of seed consists of 1⅓ ounces Arasan

SF plus 1 ounce of either aldrin, chlordane, dieldrin, or lindane applied in slurry form.

Tests were made on the effect of storage on treated seed. No injury resulted from 58 weeks of storage when the temperature was 40° to 50° F; nor was there any reduction in the efficiency of the pesticides. At a storage temperature of 70° to 80° F there was serious injury to the seed from 31 weeks' storage. This injury was caused by the high temperature and not by the pesticides, because it was just as severe in untreated seed.

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